DAMES & MOORE

SOIL MECHANICS ENGINEERS

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421 3RD AVENUE WEST · SEATTLE 99, WASHINGTON · ATWATER 4-8160

RESIDENT PARTNER: WILLIAM ENKEBOLL

January 19, 1959

Austin Associates
2930 Fourth Avenue South
Seattle 4, Washington

Attention: Mr. B. T. Bjornstad

Gentlemen:

Five copies of our "Report of Foundation Investigation, Proposed Furnace Brazing Facilities, East Side of Boeing Field, Seattle, Washington, for the Boeing Airplane Company" are herewith submitted.

The scope of the investigation was planned in discussions between Mr. B. T. Bjornstad and Mr. Jack Salsburg of Austin Associates and Mr. Joseph Lamont, Jr. of Dames & Moore. The results of the field explorations and our conclusions were discussed with you as the data became available during progress of the investigation.

Yours very truly,

DAMES & MOORE

By Joseph Lamont Jr.
Joseph Lamont, Jr.

JL:fm

REPORT OF FOUNDATION INVESTIGATION

PROPOSED FURNACE BRAZING FACILITIES

EAST SIDE OF BOEING FIELD

SEATTLE, WASHINGTON

for the

BOEING AIRPLANE COMPANY

SCOPE

We present in this report the results of a Foundation Investigation at the site of Proposed Furnace Brazing Facilities to be constructed on the East Side of Boeing Field in Seattle, Washington, for the Boeing Airplane Company. The site is located between two existing airplane hangars known as Buildings 3-960 and 3-965, and occupies an area approximately 121 feet by 167 feet in plan dimensions. The location of the site, with respect to the existing adjacent structures, is shown on the Plot Plan, Plate 1.

The scope of the foundation investigation is to determine the nature of the soils underlying the site, to recommend the most feasible means of supporting the proposed structures, to provide design values to be used in foundation design, to estimate the settlement which would result under the recommended means of support, and to consider whether or not vibratory equipment would have an adverse effect on the proposed facilities.

DESIGN CONSIDERATIONS

The principal units of construction consist of a traveling furnace, four hearths, a number of chemical storage tanks, and a structure to house all of the aforementioned units.

Four hearths measuring 12 by 26 feet in plan dimensions will be aligned in an end-to-end position across the north portion of the site. We understand that each hearth will exert a load of approximately 70,000 pounds on the foundations when in operation. The load of each hearth will be carried to a concrete slab by a group of jacks which will provide a means of releveling the units after construction. An additional load of approximately 300 pounds per square foot will be imposed on the foundations between the jack units. A clear space of approximately four feet will separate adjacent hearths. Temperatures in the hearths are expected to reach a maximum of 2300 degrees Fahrenheit. Air space around the supporting jacks will serve as a means of conducting heat away from the hearths.

A traveling furnace unit will operate over the hearths and will be supported on rails resting on shoulders of the concrete foundation on each side of the hearth units. The rails carrying the traveling furnace will be 16 feet apart. The furnace will be supported on a total of eight wheels, and the load imposed will be 20,000 pounds per wheel. The four wheels on each rail will be spaced 7'-4" apart.

Tanks used for chemical storage, rinsing, and drying operations will be located on the south portion of the site. The tanks will be located in a concrete-walled pit the depth of which has not been finally determined. Tentative thinking by the design engineers at the present time is that this pit will extend some 13 feet below the existing ground surface. The tanks to be located inside the pit are expected to be approximately four feet in width, 30 feet in length, 25 feet in height, and of steel construction. The specific gravity of the contents in the chemical milling tanks is expected to be approximately 1.6.

The structure which will house the furnace brazing facilities is expected to be on the order of 50 feet in height and of industrial type construction. Column loads are not known at the present time, but analyses have been accomplished for a range of load conditions.

SITE CONDITIONS

The surface of the site is paved with a six-inch concrete pavement, and in the past has been used as an access area for aircraft entering and leaving the two adjacent hangar structures. Numerous cracks and some distortion have developed, and it is anticipated that the existing pavement will be removed in the construction operations.

The soils below the pavement to a depth of approximately 11 feet in Boring 1 and nine feet in Boring 2 consist of hydraulically-placed fill, and are classified as fine to medium sand and sandy loam. These soils are moderately firm and dense. Below this upper hydraulic fill, finer-grained soils were encountered consisting of alternating thin layers of sandy loam, silty loam, and some fine sand. These soils occur only to a depth of 18 feet in Boring 1, but extend to a depth of 31 feet in Boring 2. These soils are very wet since the ground water level at the site is at a depth of approximately nine feet below the surface, which is nearly coincident with the upper boundary of this material. The sand which occurs in this material is fine-grained and rather loose, and in general, this stratum is fairly weak and quite compressible. A layer of firm sand exists below the compressible materials, and is of substantial thickness in Boring 1 but relatively thin in Boring 2. The soil gradually becomes finer with increasing depth below this sand, and a layer of gray silty loam approximately 10 to 12 feet in thickness was encountered at depths of 36 and 39 feet below the surface in the two borings. The silty loam is underlain by a firm sandy loam and gravel deposit which contains considerable seashells. The borings were terminated in these firm soils.

Upon completion of drilling, the borings were left open for several days to obtain information concerning water levels. As the casing was withdrawn the boring walls collapsed to a depth of approximately nine feet below the surface, which is the indicated water table. After the boring walls had collapsed to this point, no further rise in the water table was found, although the upper soils later collapsed into the boring cavity. A more detailed description of the field explorations, including the log of each boring, is presented in Appendix A.

DISCUSSION AND RECOMMENDATIONS

GENERAL:

In determining whether or not the proposed facilities may be safely supported on spread or mat foundations in the upper firm sand, it is essential that the pressures imposed by such foundations do not overstress the underlying weaker, compressible soils, and that the settlements which would occur under the imposed loads are within tolerable limits for the particular unit. With these criteria in mind, and utilizing the data obtained from the field explorations and laboratory tests, we have evaluated the foundation requirements for the building foundations, the hearths and traveling furnace, and the storage facilities. Our conclusions regarding the foundation support of each of these units are presented in the following sections.

BUILDING FOUNDATIONS:

We recommend that the proposed building housing the furnace brazing facilities be supported on spread foundations founded in the upper hydraulic fill soils. For footings supported in the upper five feet below the surface, we recommend that the maximum allowable bearing pressure be limited to 2500 pounds per square foot. This value applies to the total of all loads--dead, live, and seismic--exclusive of the weight of the foundations and backfill over the footings. From the standpoint of settlement, it is preferable that the footings be kept as high as possible to provide a maximum thickness of firmer clean sand above the weaker compressible sandy loam and silty loam soils existing below the sand. The minimum footing depth should be not less than 18 inches to provide adequate protection against frost penetration. If footings are supported at depths greater than five feet below the surface, the allowable bearing pressures would become smaller until a limiting pressure of 1250 pounds per square foot is reached on the weaker sandy loam and silty loam soils.

Since the column loads have not been evaluated at the time of this writing, we have estimated the range of ultimate settlements for a range of footing sizes and loads designed in accordance with the maximum bearing value as recommended in the previous paragraph. In these evaluations, we have assumed that the footings will be supported at a depth of three feet below existing grade; and that dead plus real live loads which are effective in causing settlement will be approximately two-thirds of the total load. The settlements of footings at greater depth would be larger. The estimated settlements are indicated in the following table:

FOOTING SIZE	COLUMN LOAD IN POUNDS	ULTIMATE SETTLEMENT IN INCHES
4' X 4'	40,000	0.2 - 0.4
5' X 5'	62,500	0.3 - 0.5
6' X 6'	90,000	0.4 - 0.6
7' X 7'	122,500	0.5 - 0.8
8' X 8'	160,000	0.6 - 0.9

Approximately 50 per cent of these settlements are expected to occur rapidly as the load is applied; approximately 90 per cent is expected within one year.

HEARTHS AND TRAVELING FURNACE:

The pressures to be imposed by the hearths, as determined from the design data provided to us, will be approximately 525 pounds per square foot. These pressures can be safely sustained by the upper sandy soils and will not overstress the underlying weaker soils. Therefore, we recommend that the hearths and the traveling furnace be supported on a mat foundation provided the magnitude of settlement would not impair the operation of the equipment.

Based on imposed loads of the indicated magnitude, we estimate that ultimate settlement of the hearth units would be on the order of one inch, assuming the hearths are founded at a depth of three feet below grade. This estimated settlement includes the effect of adjacent hearth units and also the pressures imposed by the furnace unit when immediately adjacent to a given hearth. Settlements would be greater if the hearths are founded at greater depth. While the high temperatures in the hearths may transmit some heat into the foundation soils, no additional settlement due to shrinkage is expected since the upper soils are clean, granular material. As in the case of the building foundations, we recommend that the bottom of the hearth foundations be placed at as high a grade as possible. If foundations must be supported at depths greater than five feet below the surface, pile support should be considerex

The loads imposed by the traveling furnace also will develop settlement, and the magnitude of this settlement is expected to be approximately three-fourths of an inch. The differential movement between the hearths and the furnace is dependent on the time at which each load is applied with respect to the other, but is not expected to exceed approximately one-half inch.

The settlements of both the hearth and furnace units are expected to occur fairly rapdily, with about 50 per cent to occur as load is applied, and 90 per cent within approximately one year.

STORAGE FACILITIES:

If the proposed chemical storage facilities to be built in the vicinity of Boring 2 were soil-supported at a depth of 13 feet below existing grade, settlements ranging from two and one-half to three inches would result due to the compressibility of the supporting soils. In addition, any excavation made into the sandy loam and silty loam soils which exist below a depth of nine feet would require dewatering as the grain-size distribution of this material is such that the soil would readily become "quick". Such dewatering would have to be accomplished with wellpoints. Pumping from sumps in this material would not be satisfactory.

We recommend that the proposed storage facilities be supported on wood piling. The piles should be driven through the underlying layers and gain support on the sandy loam and gravel which is encountered at Elevation -40 in Boring 2. Piles supported in such fashion will safely carry loads of 25 tons. Some firm driving may be expected between Elevations -22 and -27, and our analyses indicate that it would be possible to gain support for 20-ton capacity piles in this zone. However, piles so supported would impose appreciable pressures on the underlying silty loam with the result that settlements on the order of one and one-half inches would result. Thus, to prevent such settlement and insure adequate support, we recommend that piles terminate in the firm soil below Elevation -40. When this firm soil is encountered, the driving resistance will increase rapidly. Two feet of penetration into the firm soil will be satisfactory, and a driving criteria of six blows per inch may be considered as practical refusal in this material. Care should be taken not to damage the piles through overdriving.

If at all possible, we recommend that the bottom of the proposed storage pit be raised from the presently planned depth of 13 feet to a minimum depth of seven feet below the existing grade. This would allow two feet of clean sand below the bottom of the slab which should be sufficient to prevent an upward movement of soil in the bottom of the excavation, and would preclude the necessity of excavating into the weaker fine-grained soils below water level. If the tanks cannot be raised sufficiently, we recommend that the fine-grained soils below a depth of nine feet be dewatered prior to excavating these soils so that such excavation can be accomplished in the dry, and thus avoid the development of a "quick" condition.

VIBRATORY EQUIPMENT:

In dealing with possible vibration problems, it is necessary to consider each case on the basis of the actual forces to be developed. Since it is not known at the present writing if any of the installed equipment will develop unbalanced forces which might cause vibration of the foundations, no detailed evaluation of this problem has been attempted. However, the loose, fine granular nature of the weaker soils which occur below a depth of nine feet is such that machine vibrations would be expected to cause some additional settlement of this material. If it is found in the design of the various units that vibratory loads would be imposed on the foundations, we suggest that the final design of the foundations be delayed until a further review of this problem can be accomplished.

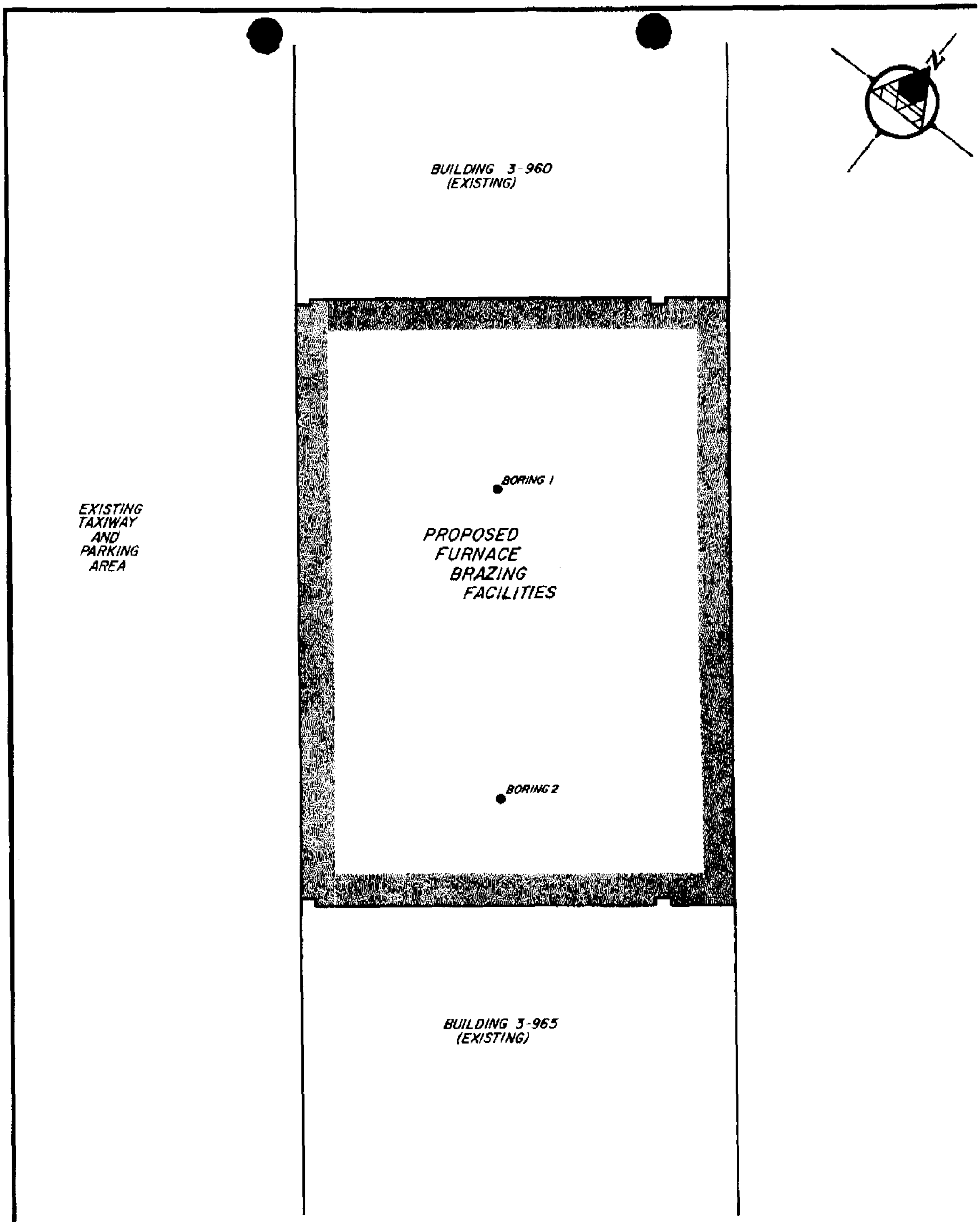
Respectfully submitted,

DAMES & MOORE

By Joseph Lamont Jr.
Joseph Lamont, Jr.

January 19, 1959

JOSEPH LAMONT
STATE OF WASHINGTON
REGISTERED
PROFESSIONAL ENGINEER



PLOT PLAN

FEET
10 5 0 10 20 30 40 50

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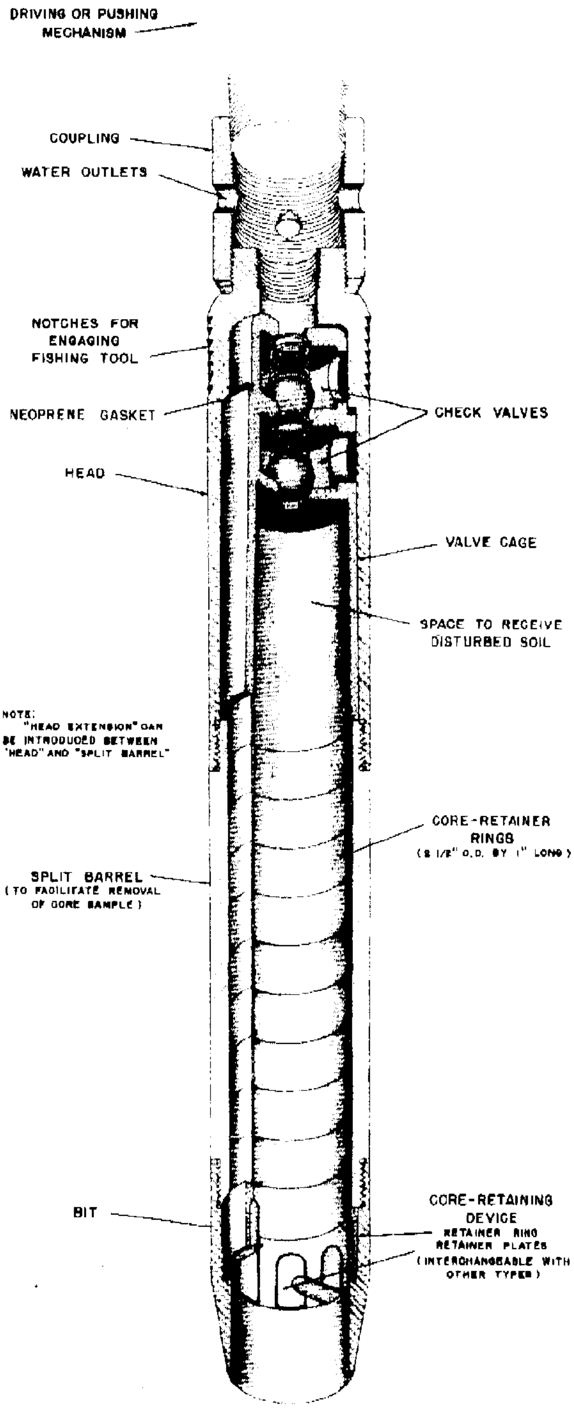
APPENDIX A

FIELD EXPLORATIONS

The soils underlying the site of the Proposed Furnace Brazing Facilities were explored by drilling two borings to depths of 53½ and 54 feet with power-operated, cable-tool drilling equipment. The locations of the borings are shown on the Plot Plan, Plate 1. The soils encountered in the explorations were classified in the field by visual and textural examination, and a continuous record of the soil profile in each boring was maintained by our field engineer. Undisturbed samples were obtained at intervals of approximately five feet in each boring utilizing a sampler of the type illustrated on page A-2. A graphical representation of the soil profile in each boring is shown on Plates A-1 and A-2, Log of Borings. The nomenclature used in classifying the soils is described in the Soil Classification Chart on page A-3.

SOIL SAMPLER TYPE U

FOR SOILS DIFFICULT TO RETAIN IN SAMPLER
U. S. PATENT NO. 2,318,062



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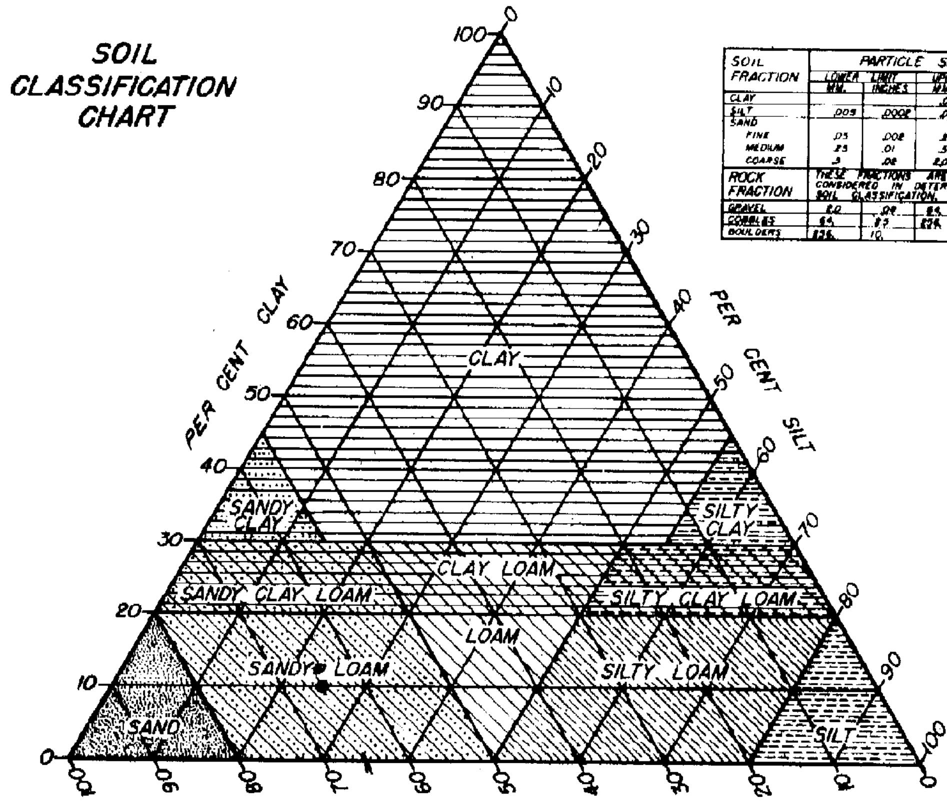
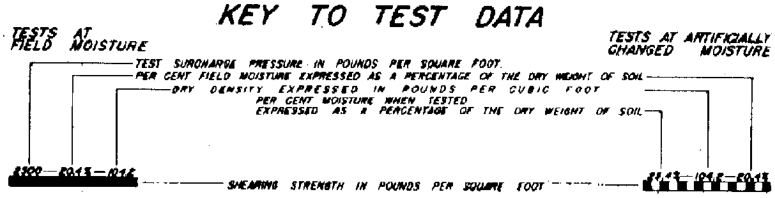
SOIL CLASSIFICATION CHART AND KEY TO TEST DATA



SOIL FRACTION	PARTICLE SIZE			
	LOWER LIMIT		UPPER LIMIT	
	MM.	INCHES	MM.	INCHES
CLAY			.005	.0002
SILT	.005	.0002	.05	.002
SAND				
FINE	.05	.002	.25	.01
MEDIUM	.25	.01	.5	.02
COARSE	.5	.02	2.0	.08
ROCK FRACTION	THESE FRACTIONS ARE NOT CONSIDERED IN DETERMINING SOIL CLASSIFICATION.			
GRAVEL	2.0	.08	64	2.5
COBBLES	64	2.5	256	10
BOULDERS	256	10		

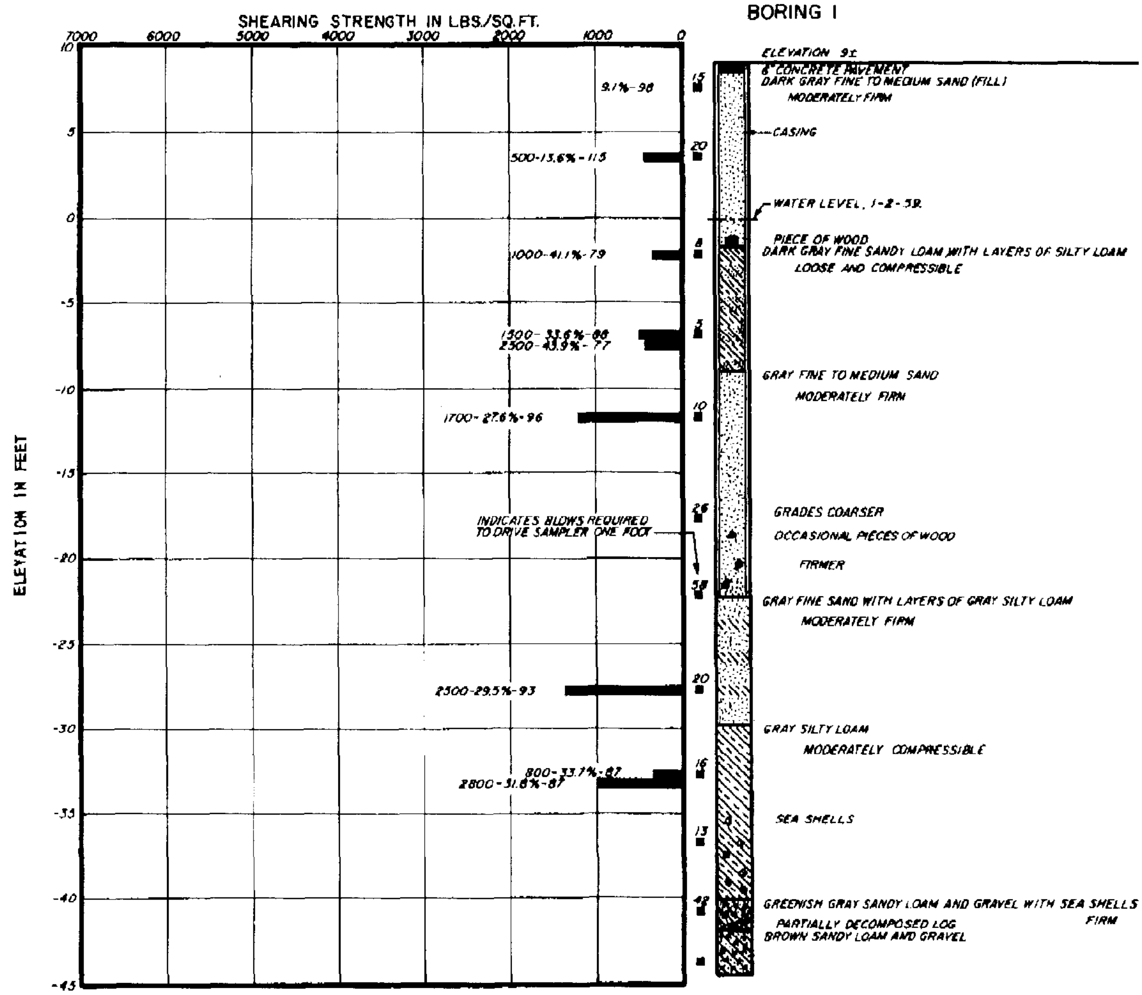
(PERCENTAGES GIVEN ARE BY DRY WEIGHT)

KEY TO TEST DATA



■ INDICATES DEPTH AT WHICH UNDISTURBED SAMPLE WAS EXTRACTED

17.11(1)



LOG OF BORINGS

NOTE:
ELEVATIONS REFER TO CITY OF SEATTLE DATUM.

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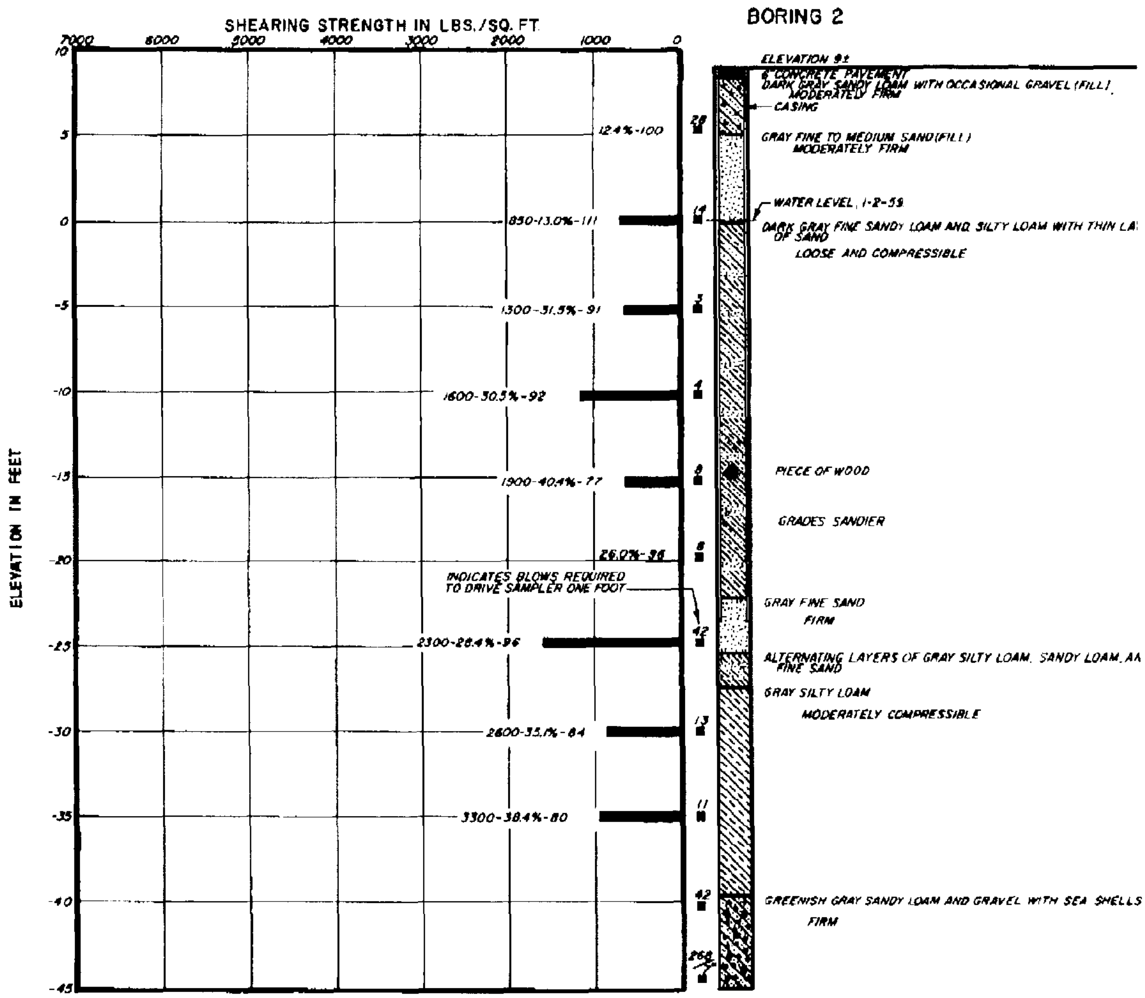

LOG OF BORINGS

DAMES & MOO

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SEA404319

APPENDIX B

LABORATORY TESTS

The physical characteristics of the foundation soils were determined in a series of laboratory tests on representative undisturbed samples obtained from the borings. The testing program included direct shear tests, consolidation tests, moisture and density determinations, and a grain-size analysis.

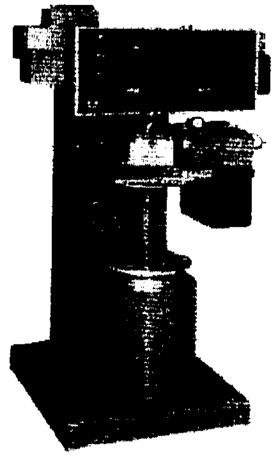
The shearing strengths of the soil were determined from the results of the direct shear tests. The method used in performing the shear tests is described on page B-2. A constant rate of shearing deflection was maintained throughout each test. The test results are shown at the left of the sample notations on the log of each boring on Plates A-1 and A-2. The nomenclature used in presenting the shear test data is described in the Key to Test Data on page A-3.

Consolidation tests were performed on selected samples of compressible soils to provide data for use in settlement evaluations. The method followed in performing these tests is described on page B-3. The results of the tests, which show the consolidation in inches per inch for various intensities of loading, are presented on Plate B-1, Consolidation Test Data.

Moisture and density determinations were performed in conjunction with each of the direct shear and consolidation tests, and in addition, were also performed on certain other samples to aid in the comparison of soils at various depths in the two borings. The results of these tests are shown at the left of the sample notations on the log of each boring on Plates A-1 and A-2.

A grain-size determination was made on a sample of the compressible soil which occurs below a depth of approximately ten feet in order to determine the degree of silt and clay fines which are present with the sand in this material. These data were subsequently used in evaluations of the probability of developing a "quick" condition in any excavations which might extend into this layer of soil. The grain-size distribution curve is presented on Plate B-2.

METHOD OF PERFORMING DIRECT SHEAR AND FRICTION TESTS



DIRECT SHEAR TESTING MACHINE

Direct shear tests are performed to determine the shearing strengths of soils. Friction tests are performed to determine the frictional resistances between soils and various other materials such as wood, steel, or concrete. The tests are performed in the laboratory to simulate anticipated field conditions.

Each sample is tested within three brass rings, two and one-half inches in diameter and one inch in length. Undisturbed samples of in-place soils are tested in rings taken from the sampling tool in which the samples were obtained. Loose samples of soils to be used in constructing earth fills are compacted in rings to predetermined conditions and tested.

Direct Shear Tests

A three-inch length of the sample is tested in direct double shear. A constant pressure, appropriate to the conditions of the problem for which the test is being performed, is applied normal to the ends of the sample through porous stones. A shearing failure of the sample is caused by moving the center ring in a direction perpendicular to the axis of the sample. Transverse movement of the outer rings is prevented.

The shearing failure may be accomplished by applying to the center ring either a constant rate of load, a constant rate of deflection, or increments of load or deflection. In each case, the shearing load and the deflections in both the axial and transverse directions are recorded and plotted. The shearing strength of the soil is determined from the resulting load-deflection curves.

Friction Tests

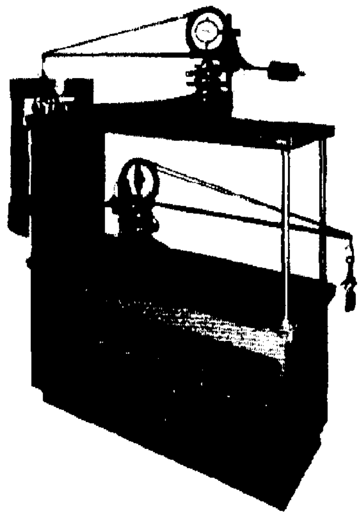
In order to determine the frictional resistance between soil and the surfaces of various materials, the center ring of soil in the direct shear test is replaced by a disk of the material to be tested. The test is then performed in the same manner as the direct shear test by forcing the disk of material from the soil surfaces.

417.1 (rev.)

METHOD OF PERFORMING CONSOLIDATION TESTS

Consolidation tests are performed to evaluate the volume changes of soils subjected to increased loads. Time-consolidation and pressure-consolidation curves may be plotted from the data obtained in the tests. Engineering analyses based on these curves permit estimates to be made of the probable magnitude and rate of settlement of the tested soils under applied loads.

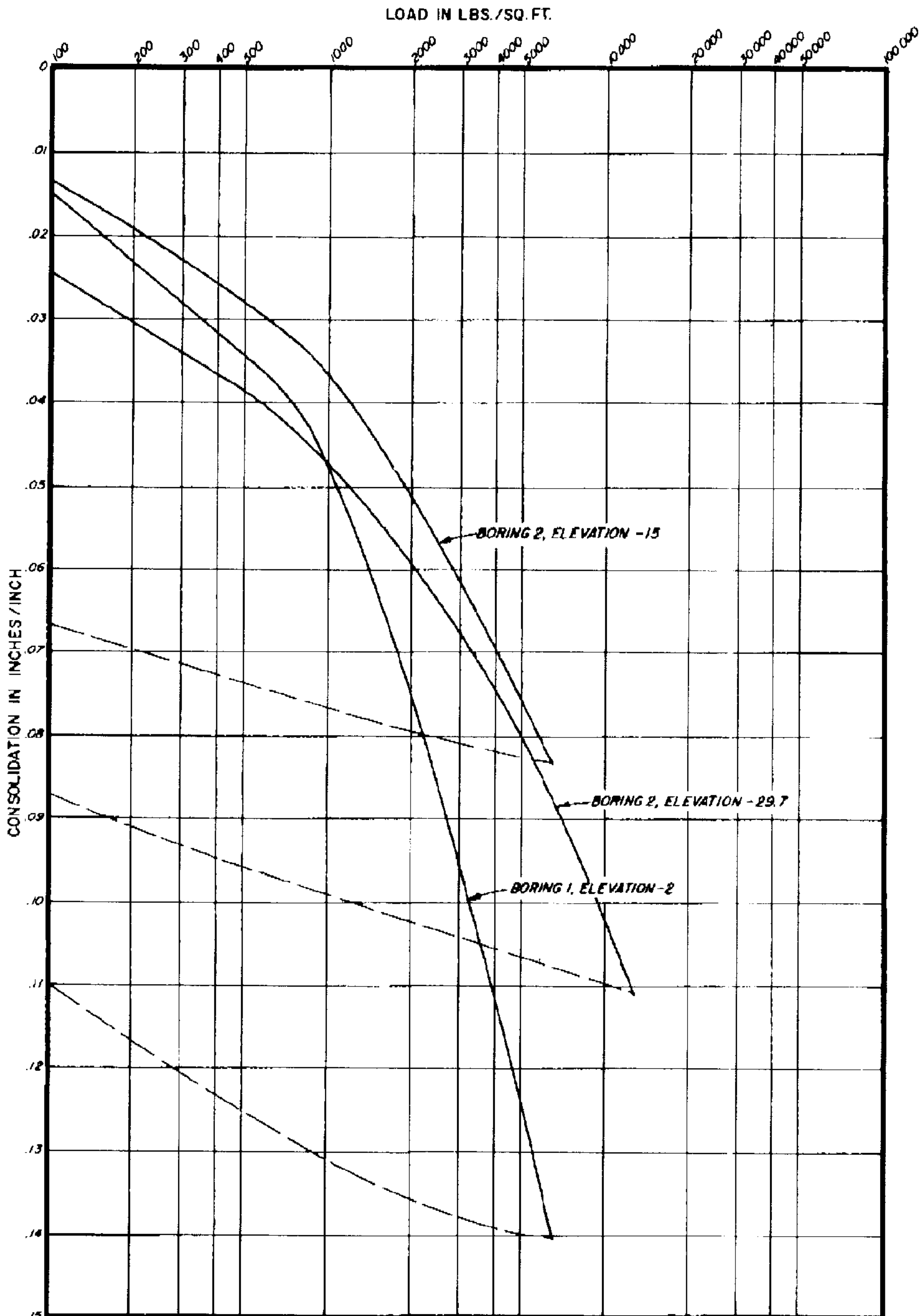
Each sample is tested within a brass ring two and one-half inches in diameter and one inch in length. Undisturbed samples of in-place soils are tested in rings taken from the sampling tool in which the samples were obtained. Loose samples of soils to be used in constructing earth fills are compacted in rings to predetermined conditions and tested.



CONSOLIDATION MACHINES

In testing, the sample is rigidly confined laterally by the brass ring. Axial loads are transmitted to the ends of the sample by porous disks. The disks allow drainage of the loaded sample. The axial compression or expansion of the sample is measured by a micrometer dial indicator at appropriate time intervals after each load increment is applied. Each load is ordinarily twice the preceding load. The increments are selected to obtain consolidation data representing the field loading conditions for which the test is being performed. Each load increment is allowed to act over an interval of time dependent on the type and extent of the soil in the field.

Soils saturated in the field are tested submerged in water. The effect of increased moisture content on partially saturated soils is determined by adding water to the sample during the test.



BORING	ELEVATION	SOIL TYPE	MOISTURE CONTENT BEFORE	MOISTURE CONTENT AFTER	DRY DENSITY IN LBS./CU.FT.
1	-2	GRAY SILTY LOAM	51.2%	42.4%	71
2	-15	GRAY FINE SANDY LOAM	41.0%	34.2%	79
2	-29.7	GRAY SILTY LOAM	39.0%	33.0%	82

CONSOLIDATION TEST DATA

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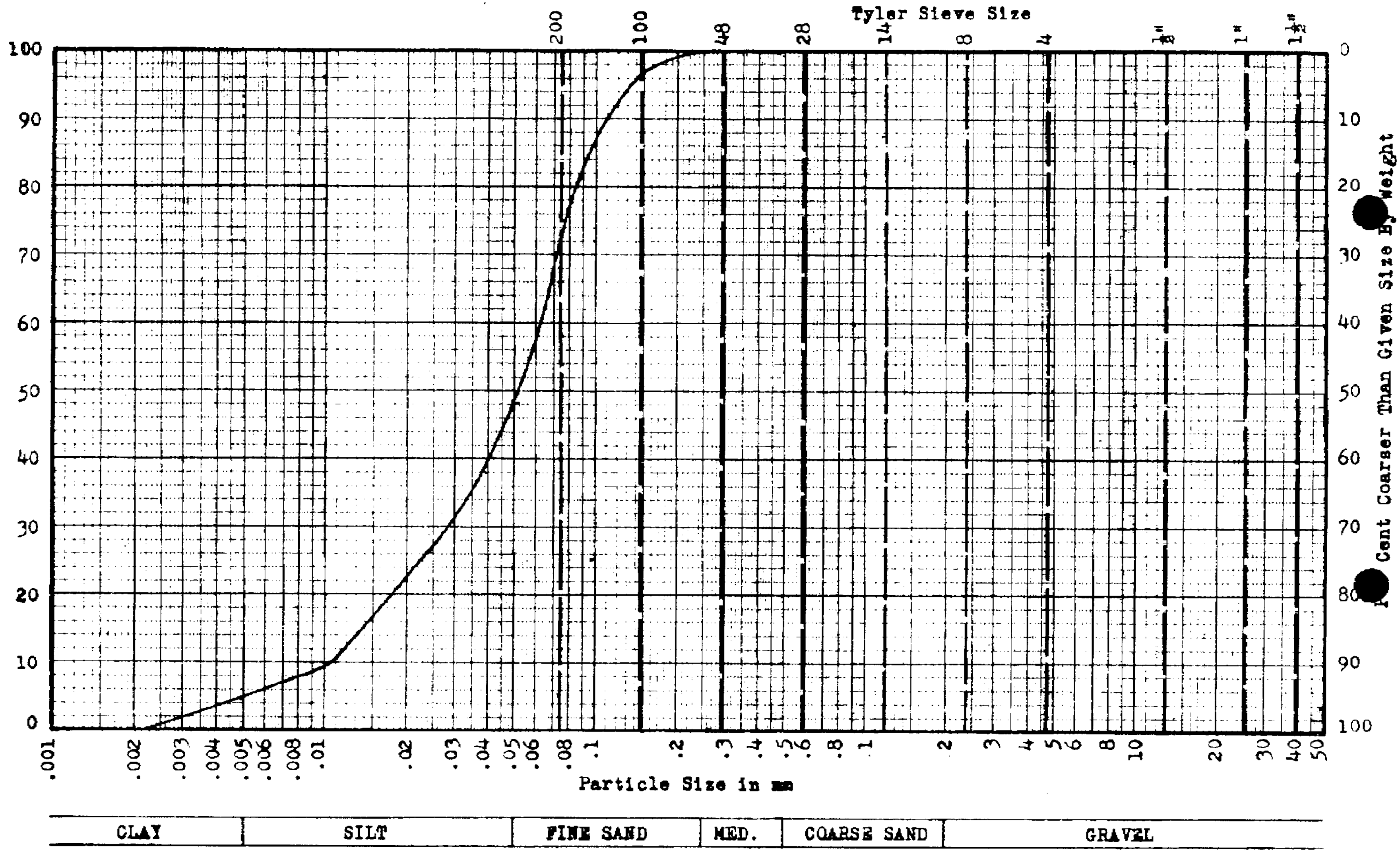
57.2

Job No. 675-U Name BOEING AIRPLANE CO.
Soil Classification FINE SANDY LOAM

Date Sampled 12-31-59 By RAP
Date Tested 1-14- By RAP



SAMPLE FROM BORING 1, ELEVATION -6.7

KCSlip4 37794

SEA404324

King County Engineer
Materials Testing Laboratory
Redmond, Washington
June 30, 1961

To: Mr. Walter Barbo
From: Irvin A. Potter
Subj: Foundation Testing for New Hangar #4 (7777)

1. Enclosed are boring logs and soil reports from tests conducted at the new hangar site.

2. The test holes were numbers 3 and 7 as indicated on the Architect's print.

There are a couple of laboratory reports yet to be compiled which I shall forward to you for your records, but which will not alter the nature of this report.

3. This type of soil does not lend itself well to vertical loads of the magnitudes required for this building, neither would it be satisfactory for the lateral pressures imposed by a vaulted structure.

4. I would recommend the following: (a) The lateral pressures could be readily taken care of by tying the truss across--going through or under the floor. This would leave only the incidental thrust of wind, propeller blast, etc.
(b) Depending upon the design bearing required per pile, wood piles should give satisfactory support. The frictional resistance of this material should be, conservatively, at least 600 pounds per square foot. I would suggest driving one or two test piles in a usable location, starting with 45' piles to determine the final length to order.

5. I hope that this information is helpful and if you feel that there is anything further that the Materials Lab of the King County Engineer may do, please call us.

Yours very truly,
Irvin A Potter
Irvin A. Potter
Materials Testing Laboratory

cc: Walt Wheeler

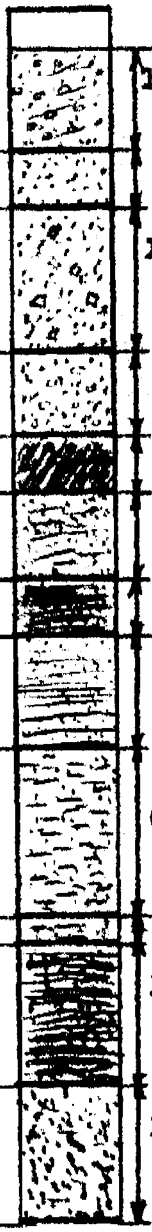
KCSlip4 37795

SEA404325

BORING LOG

King County Airport New Hangar — June 27, 1959

Hole No. 7 — Crew: Potter, Adair, Breitsprecher



Depth	Legend	DESCRIPTION OF MATERIALS (Type, wet color, consistency, and general remarks)	Miscellan Data
		Surface	
1'2"	14"	Light brown, gravelly sandy loam (fill material)	Hand tool Hand Auge
1'9"	7"	Light brown, medium grained sand (fill)	Diam. 5"
3'1"	16"	Dark brown, medium grained sand with wood fragments (fill)	Length 18 Total dep of hole 1
3'7"	6"	Dark brown gravelly, sandy loam (fill)	
3'11"	4"	Oil impregnated gravel and sand (old paving)	
4'7"	8"	Light brown sandy loam (fill)	
4'9"	2"	Light blue silty clay (fill)	
5'3"	6"	Black, silty loam (original top soil)	
10'0"	60"	Light brown, sandy silt (original sub-soil)	
10'3"		-10' Water table	
11'6"	15"	Light gray, silty clay with many decayed wood fragments (original sub-soil)	
13'0"	18"	Black, well-sorted medium to coarse grained sand	

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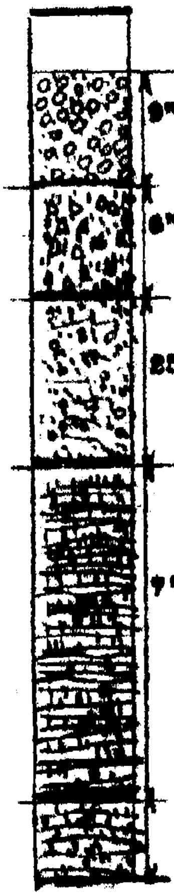
SEA404326

BORING LOG

King County Airport New Hangar June 29, 1961

Hole No. 3 Crew: Potter, Adair, Breitsprecher



Depth	Legend	DESCRIPTION OF MATERIALS (Type, wet color, consistency, and general remarks)	Miscellaneou Data
		Surface	
		9" Concrete Parking Apron	4" Core d for concre
0'9"			
		6" Crushed Stone Base	2" power auger
1'3"			
		25" Light brown, gravelly sandy loam Possibly fill material	
3'4"			
			Samples obtained from auge screws
		7'8" Light blue silty clay	
10'0"		Water table -10'	
11'0"			

KCSlip4 37797

SEA404327

KING COUNTY ENGINEER
MATERIALS LABORATORY
REDMOND WASH.

District: 2

Type of Aggregate: Material from Boeing field

Sample No. 1 Date Sampled: 6/27/61

Name of Pit:

Location: Test Hole # 3

Crushed by:

Sampled at:

To be used at: Contract No.

COARSE AGGREGATE				FINES FROM COARSE AGGREGATE			
Passing Screen	Specif. Req'ments	% Passing	% Fracture	Passing Screen	Specif. Req'ments	% Passing	% Fractur
5/8		100		# 4		98.5	
1/2		99.7		# 8		97.2	
3/8		99.4		# 16		90.3	
1/4		99.0		# 40		88.5	
				# 60		58.3	
				# 80		51.0	
				# 100		34.3	
				# 200		19.5	

REMARKS: SAND EQUIVALENT - 9.0

Date: 6/30/61 By: [signature] A. Potter

KCSlip4 37798

SEA404328